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COMPARISON OF BOUNDARY LAYER TRIPS OF DISK AND GRIT TYPES ON AIRFOIL PERFORMANCE AT TRANSONIC SPEEDS

by
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COMPARISON OF BOUNDARY LAYER TRIPS OF DISKS AND GRIT TYPES ON AIRFOIL PERFORMANCE AT TRANSONIC SPEEDS

COMPARAISON DE L'EFFET DES DÉCLENCHEURS DE TRANSITION DE COUCHE LIMITE DES TYPES À DISQUES ET À GRAINS SUR LES CARACTÉRISTIQUES DES PROFILS AÉRODYNAMIQUES AUX VITESSES TRANSSONIQUES

by/par

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National Aeronautical Establishment

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SUMMARY

The effects on aerodynamic performance of a supercritical airfoil applying disk or grit tripping for boundary layer transition has been investigated for a typical supercritical airfoil at transonic speeds. It is observed that by allowing the laminar flow passing through the space between the disks, transition takes place a short distance downstream from the disk trip line. The boundary layer developed downstream from the disk trip is therefore slightly thinner than that from a grit trip. The vortex generating mechanism of the disks may also enhance this development. This small difference has negligible effect on aerodynamics of the airfoil at low lift. However, at high lift, the difference in boundary layer developments is amplified by the strong shock wave and the severe adverse pressure gradient. The thinner and more energetic boundary layer induced by the disk trip will yield higher lift, lower drag and higher trailing edge pressure.

RÉSUMÉ

On a étudié les effets sur les caractéristiques aérodynamiques à des vitesses transsoniques de l'application à un profil aérodynamique supercritique type de déclenchement de la transition de couche limite par des disques ou des grains. On constate qu'en laissant l'écoulement laminaire passer entre les disques la transition se produit à une faible distance en aval de la ligne de disques. La couche limite créée en aval des disques est par conséquent légèrement plus mince que celle produite par des grains. Le mécanisme de création de tourbillon des disques peut aussi accroître ce phénomène. Cette faible différence a un effet négligeable sur le comportement aérodynamique du profil en conditions de faible portance. Cependant, en conditions de portance élevée, la différence dans le développement des couches limites est amplifiée par la forte onde de choc et le fort gradient de pression adverse. La couche limite plus mince créée par les disques donnera une portance plus élevée, une traînée plus faible et une pression de bord de fuite plus élevée.

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List of Symbols

c	chord length
C_{D_W}	drag coefficient, wake integration
C_{L_p}	lift coefficient, pressure integration
$C_{p_{T.E.}}$	pressure coefficient, trailing edge
k	roughness height
M_∞	free stream Mach number
Re_c	free stream Reynolds number based on chord length
x_s	shock position on model
x_t	transition location
α	angle of attack

1. INTRODUCTION

Airfoil performance at transonic speed is very sensitive to the boundary layer development over the airfoil. When simulating the boundary layer flow at flight Reynolds number in a wind tunnel, at a lower Reynolds number, artificially induced transition at specific locations on the model is usually applied. The location is determined by the aerodynamic parameters to be simulated such as the shock wave position, trailing edge pressure or total drag of the model.[(1)] The most common practice of inducing artificial transition is applying roughness locally on the model surface. The technique has been developed and guidelines for its applications can readily be followed. (See References 2, 3, 4, 5 and Sections 2.3.2 and 4.9 of Reference 1). The simplest form of the technique is to distribute small roughness particles randomly on a narrow strip of adhesive materials. Carborundum and ballotini are two commonly used roughness elements. To apply the trip on the model, an adhesive strip is first painted or sprayed on the desired location and the particles are then sprinkled on the strip or blown into a dust cloud over the model and then settled on the strip. This simple way of application however cannot control the particle density precisely and in most cases, its acceptability is determined by comparing with a sample trip or simply by experience. Another undesirable nature of the grit trip is loss of particles after repeated runs. The effectiveness of the trip decreases as the particle density reduces and eventually the trip has to be replaced.

In contrast to the random distribution of roughness particles, discrete roughness elements spaced regularly and arranged in rows are also frequently in use. The roughness element could be in the form of

a sphere, a short cylinder (a disk) or other geometric shapes[3]. These elements have to be installed one by one and the process is laborious. However, the roughness height and the spacing for such a strip can be precisely measured and the elements can be mounted firmly to withstand the pressure and shear forces that they may encounter during the test. If any element has been removed, it can be easily detected and replaced individually independent of the other elements. Because of these advantages the discrete roughness element strip has been adopted by a number of aircraft manufacturers.

The effectiveness of the discrete roughness element strip has been investigated by von Doenhoff and Braslow for low speed flows[3]. The applications to transonic flows has been recently studied by Sinclair and Strike[6]. By applying the transition strip on a cone with 7 degree half angle, Sinclair and Strike estimated the critical roughness Reynolds number to be 600 to 800, identical to those recommended by Braslow and Knox for low speed flows[2]. Thus the roughness height could be designed with the same criterion as that for the grit strip ultilizing the data graphs in Reference 2. The effectiveness of the disk type tripping has been compared with the grit type by Wright based on tests of a large number of models of airfoils and wings[7]. Wright concluded that the disk height could be designed by Braslow's rule, as in Reference 6, and the disk strip and the grit strip with the same roughness height gave the same overall drag. The trip drag, however, was very sensitive to the roughness height in contrast to the findings in Reference 2. These investigations all showed that the disk trip could be applied with more confidence than the grit type as far as total drag was concerned.

It should be noted that for grit tripping, turbulent flow starts immediately downstream of the strip rear edge. For disk tripping the turbulent flow does not start right downstream of the rear-edge line of the disks. Flow visualizations show that the disk works like a vortex generator and induces two vortices trailing downstream separated by a distance approximately equal to the disk diameter (See also Section 4.9 of Reference 1). Laminar flow passes through the disk line through the gaps between the disks. As observed from flow visualization there is no clear demarcation line between laminar and turbulent flow. The laminar flow passing between the discs is gradually transformed to turbulent flow by the disc generated vortices and fully turbulent flow is usually established after about 100 disc heights[(6)] (Fig. 1). The slight difference in transition location may not have a significant effect on the total drag as shown in Reference 7. However, simulations of transonic flow are extremely sensitive to the boundary layer development[(1,8)]. It is therefore quite possible that the difference in transition process between disk and grit tripping, for the same trip location, may have an influence on sensitive flow parameter such as the shock wave location, the trailing edge pressure and the on-set of the rear separation.

The purpose of this investigation is to establish whether the two trip techniques affect the aerodynamic performance of an airfoil differently at transonic speed. The investigation was performed on a two-dimentional airfoil section with both forward and rear tripping. A single row disk strip was employed for all tests with chord Reynolds numbers ranged from 4 to 15 million. The results are then compared with data from an earlier investigation with grit strips at the same conditions[(9)].

2. Specifications of Transition Strips of Disk Type and Test Conditions

The geometry and arrangement of the trip disks as specified by Wright[7] are adapted for the present investigation. The single-row disks have diameters of 0.045 inch and are spaced 0.10 inch apart. The disks are in the form of short circular cylinders. The required disk thickness is derived from the roughness Reynolds number, Re_k, with a value of 600, as recommended in Refs. 6 and 7. The same criteria was also used for determining the grit size in the earlier investigation. With the disk thicknesses selected for the various Reynolds numbers, the roughness shape parameter (diameter/height) ranged from 9 to 22.5. A mold of the disks in the form of a plastic tape with holes punched and spaced at specific dimensions is first prepared. The tape is mounted on the desired location of the model and the holes on the tape are then filled with epoxy type material. After the material is hardened, the tape is removed and a row of circular disks is neatly formed. The procedure of installation recommended by Wright is given in the Appendix. The height of the disk can be set by the thickness of the tape and can be reduced afterward by a shaver, a tool specially designed for the delicate operation of removing fractions of one thousands of an inch of material. The disk height is then spot checked by a height gauge. The averaged value is considered to be the roughness height of the strip. Some typical examples of the disk strip heights applied in the present tests are shown in Table 1.

The investigation was conducted with a two-dimensional airfoil model having a sectional profile of CAST10-2/DOA-2.[10] This model has

been used extensively at NAE for boundary simulation studies, as well as for wall interference studies in a joint program with NASA Langley. Tests have covered a range of Reynolds numbers from 4 to 30 million at transonic Mach numbers with transition fixed[9,10]. Below Reynolds number 10 million, both forward and aft transitions have been tested. Transition fixing for these earlier tests were all attained with grit strips.

The present tests were conducted at a Mach number of 0.765. Reynolds numbers ranged from 4 to 15 million for forward tripping at 5% chord and 4 to 10 million for aft tripping at 30% chord, the same as for the "grit" tests. At each trip position, two roughness heights were tested. The first one corresponded to the critical height required for tripping at the lowest test Reynolds number (4.2 million). The second one had about twice the height of the first one. For each test case a full polar was obtained. The conditions of the test cases are summarized in Table 2. The tests were conducted in the NAE Two-dimensional High Reynolds number Test Facility. The description of the facility and the test set-up can be found in Reference 10.

3. Aerodynamic Effects

3.1 Forward Tripping

3.1.1 Lift

The lift coefficient versus angle of attack for the Reynolds number range investigated is shown in Fig. 2. Lift curves for two disk trip heights and a grit trip are shown for comparison. For the case with Reynolds number 15 million, grit trip data are not available.

The lift curves agree fairly well in general. For Reynolds number 8 million and below the curve with thick disks gives slightly higher C_L values at low angles of attack. At higher incidences this effect vanishes. The maximum lift coefficient and the post stall behaviour are generally in good agreement. The only notable difference appears to be that the incidence for $C_{L_{max}}$ is about 0.4 degree less for the thinner disc.

At higher Reynolds number of 10 million, the higher lift observed for the thick-disk case extends to higher incidence. However, the lift curve turns off sooner than the thin-disk case near maximum lift and yields a slightly lower value of $C_{L_{max}}$. One would expect that the thick-disks would induce a thicker boundary layer over the airfoil and the large decambering effect would give low lift[9]. However, the opposite effect is observed for the present cases. Since the decambering effect is caused by the asymmetric developments of the boundary layers at the upper and the lower surface of the airfoil, the present results imply that the boundary layers are developed more evenly for the case with the thick disks than that with the thin disks. This is indeed possible if the disks work like vortex generators. The thick disks generate stronger vortices and thus energize the boundary layer leading to more even developments at both sides of airfoil and hence less decambering. The thicker boundary layer, however, is still more likely to separate than the thin one at high incidences because of the amplification effect due to the shock and the adverse pressure gradient[8,11]. This is observed at the region near maximum lift resulting in a lower $C_{L_{max}}$.

The data with grit tripping agree very well with those with thin-disk tripping at Reynolds number 4 million as both have the same trip height. At higher Reynolds numbers the grit case yields lower $C_{L_{max}}$ and lower C_L at post-stall conditions. This may be due to a thicker boundary layer for the grit case than for the disk case due to the downstream shift of the transition of the latter or the energizing effect of the disk vortices.

3.1.2 Drag

The drag polars for the same cases are shown in Fig. 3. Below C_L about 0.5 the difference of the drag values for the cases with different disk heights is very small, about one to two counts at the most for all Reynolds numbers. This indicates that the trip drag of the disks is very small up to a disk height about twice the design value. At lift coefficients greater than 0.5 drag is consistently higher for the thick disc case. The two drag curves, however, keep nearly parallel as drag increases. As discussed in the preceding section, the thick disks induce a thicker boundary layer which is more likely to separate, hence an earlier drag rise. With grit tripping the drag is fairly close to that with disk tripping before the drag rise, but then rises more rapidly for all Reynolds numbers considered. This again indicates thicker boundary layer development for the grit case, consistent with lower lift observed in Fig. 2. Using the grit data as a reference, the difference in drag between the grit and the disk data is shown in

Fig. 4. The difference in drag is small for C_L less than 0.5 and negligible between the two disk cases. At higher C_L, the thin-disk case gives the lowest drag.

3.1.3 Trailing Edge Pressure and Shock Locations

The details of the flow over the airfoil is investigated by examining two main flow parameters: the trailing edge pressure and the the location of the shock at the upper surface. The trailing edge pressure coefficients for both disk and grit trippings are shown in Fig. 5. The trailing edge pressure variation is consistent with the observed drag variation. At low C_L there is hardly any difference between the thin- and the thick-disk cases. At higher C_L the thick-disk case gives lower trailing edge pressure than the thin-disk case, indicating again that the former induces thicker boundary layers. The grit case has the same level of trailing edge pressure as the disk cases at low lift. However, it decreases much sharper at higher lift consistent with the drag behaviour.

The locations of the shock, as defined by M(local) = 1.1 on the upper surface of the airfoil, are shown in Fig. 6. At low Reynolds numbers the thin-disk data are closer to the grit data while the thick-disk data give a slightly more upstream locations. This is expected as the thick-disk case has thicker boundary layers. At higher Reynolds numbers the disk data for both thin and thick cases are fairly close, while the grit data yield the most downstream location.

3.2 Aft Tripping

For model testing a low Reynolds numbers, simulations of shock wave locations and rear separations at some higher flight Reynolds number is usually achieved by aft tripping[1]. Thus for the present investigation transition trips were also mounted at 30% chord. Again two disk trips were tested. The thin disk had the same roughness height as the grit and the thick disk had about twice the thickness of the thin disk.

The aft tripping experiment will be meaningful only if the natural laminar boundary layer flows extend all the way to the tripping location. If the boundary layer becomes turbulent ahead of the trip, then the trip acts only as additional roughness which thicken the turbulent boundary layer downstream. The natural transition location for each Reynolds number is estimated from the data in Reference 9 and is reproduced in Fig. 7. In the graphs presented in the following sections, the lift coefficient at which the transition occurs at 30% chord is indicated by an arrow for each case. Only data at and above the indicated C_L will be discussed.

3.2.1 Lift

The lift coefficients versus the angles of attack for the cases considered are shown in Fig. 8. At low Reynolds numbers the disk thickness has negligible effect on lift. At higher Reynolds numbers the thick disk case shows a definite lower lift due to thicker boundary layer.

The grit data are consistently low for all Reynolds numbers. For the case with Reynolds number 8 million, the grit and the thick-disk data are practically the same up to the onset of separation. This shows that the boundary layer development must be fairly close for these two cases. The grit data, however, have lower value in the stall region suggesting that the boundary layer for the disk case is more energetic due to the vortex generator effect of the disks. It shou'd be noted that the stall characteristics for the aft-tripping is significantly different from that of the forward tripping, because of the different boundary layer development over the rear portion of the airfoil in the two cases.

3.2.2 Drag

The drag polars for the corresponding cases are shown in Fig. 9. The thin-disk case gives the lowest drag and the thick-disk and the grit data are again very close. As just discussed, this is indicating a thinner boundary layer for the thin-disk case. The cases with thicker disk show drag rise at lower C_L followed by consistently higher drag with increasing C_L. The difference in drag with respect to the grit data is shown in Fig. 10. The pronounced drag variations at high C_L are clearly demonstrated.

3.2.3 Trailing Edge Pressure and Shock Locations

The trailing edge pressure coefficient versus the lift coefficients is shown in Fig. 11. At the lowest Reynolds number, 4.2

million, the data for both disk cases are nearly identical. At the two higher Reynolds numbers the thick-disk case results are lower than those for the thin disk. The grit case always yields lower values than the thin disc cases and is very close to the thick-disk data at the higher Reynolds numbers, although it drops off much sooner consistent with what has been observed for the lift and drag results.

The shock locations of the corresponding cases are shown in Fig. 12. At low Reynolds number of 4.2 million, the shock location for the two disk cases are very close. At the higher Reynolds number the shock for the thin-disk case locates further downstream than for the thick-disk case, indicating a thinner boundary layer for the thin-disk case. The grit data give the aft-most shock location except for the highest C_L for all Reynolds numbers. The difference in shock locations between the three tripping configurations, however, is generally quite small, about 1% chord except at the higher C_L's where the thin disk case gives the aft-most location.

4. Concluding Remarks

An investigation of disk tripping versus grit tripping on the aerodynamic characteristics of a supercritical airfoil has been carried out at a Mach number of 0.765 and Reynolds Numbers between 4.2 to 15 million. From the analysis of the data the following conclusions are drawn:

1. The disk type roughness is just as effective for inducing transition of the laminar boundary layer as grit trips. The roughness height for

the disks required for effective tripping is the same as that of the grit trips.

2. For a single row of uniformly distributed disks, the disks work like vortex generators with a pair of vortices trailing downstream. Between two adjacent disks, laminar flow passes through the space in between and interacts with the trailing vortices. Transition is achieved a short distance downstream from the disk line.

3. The boundary layer development downstream from the disk trip is therefore slightly different from that with a grit trip. This small difference has negligible effect on the aerodynamics of the airfoil at low lift. At high lift, however, the effect is discernible.

4. At high lift, the disk trip gives slightly higher lift, lower drag and higher trailing edge pressure, all indicating a more energetic boundary layer development than for the grit trip.

5. When the disk height is larger than the critical value, the transition occurs closer to the trip line due to the stronger vortices generated by the thicker disks. The boundary layer developed downstream is also thicker than that induced by the thin disks.

6. At low lift, the thick-disk trip, up to twice the height of the thin one, has negligible effect on the aerodynamic performance of

the airfoil. The trip drag is negligible. At high lift, the thicker boundary layer reduces the lift and increases the drag and the trailing edge pressure.

7. The location of the shock wave on the upper surface of the airfoil is sensitive to the boundary layer development. Thus it is affected by the configuration difference of the trip. A difference of up to 1% chord for low and intermediate C_L is obtained between disk-tripping and grit tripping. About the same deviation is also observed for doubling the roughness height.

It is well known that the aerodynamic performance of an airfoil at transonic speed is very sensitive to the boundary layer development over the airfoil. Different roughness configurations may induce slight difference in the downstream boundary layer development, and affect the airfoil performance. At low lift the difference is minute and can probably be ignored. At high lift, however, the difference is distinguishable and more caution must be exercised when selecting the tripping configuration. Although it is not possible to state conclusively that one method of tripping is more realistic than the other, it is believed that, if high lift performance is of prime concern, grit-tripping should be used. Disk tripping with its more energetic boundary layer downstream may result in too optimistic results.

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Appendix

TRIP DISK INSTALLATION PROCEDURES

(Recommended by Boeing Company)

>CLEAN THE MODEL SURFACE THOROUGHLY BEFORE APPLYING THE PAT-BILD+ EPOXY. FLOOD THE AREA WITH SOLVENT* AND WIPE CLEAN SEVERAL TIMES. IF ONLY A SMALL AMOUNT OF SOLVENT* IS USED THE CONTAMINATION MAY MERELY BE REDISTRIBUTED ON THE SURFACE. USE PAPER TOWEL OR TISSUE AND DISCARD AFTER EACH WIPE.

>DO NOT INSTALL DISKS DIRECTLY ON TOP OF A PENCIL OR INK TRIP POSITION MARKING LINE. THE PAT-BILD+ EPOXY MAY NOT ADHERE.

>DO NOT INSTALL DISKS OVER A PRESSURE ORIFICE. COVER PRESSURE TAPS WITH A NARROW PIECE OF TAPE. INSTALL TRIP DISKS AND THEN REMOVE THE TAPE. THIS WILL RESULT IN A GAP OF ONE OR TWO DISKS AT EACH WING PRESSURE STATION WHICH IS ACCEPTABLE.

>MINIMIZE TAPE STRETCHING WHEN THE TAPE IS UNROLLED AND APPLIED TO THE SURFACE.

>APPLY PAT-BILD+ EPOXY USING CONSTANT PRESSURE.

>HOLD A FLEXIBLE SWEEP AT AN ANGLE OF ABOUT 5° TO 10° TO THE SURFACE WHEN SWEEPING THE PAT-BILD+ INTO TAPE HOLES.

>SAND THE DISKS FLUSH TO THE TAPE USING FINER SANDPAPER, ABOUT NO. 150.

+PAT-BILD Replacement Material: EVERCOAT Part No. 400 (Polyester Glazing Putty), Fibre Glass-Evercoat Co. Inc., 6600 Cornell Road., Cincinnati, Ohio 95242
2.25 lbs.

*FREON TF OR EQUIVALENT

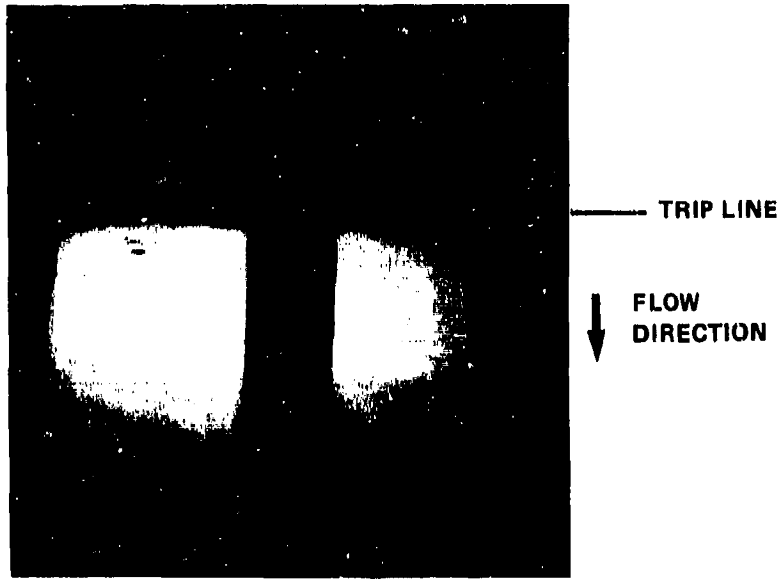
Table 1. MEASUREMENTS OF DISK HEIGHTS (in inches)

Nominal	0.0020	0.0035	0.0050
	0.0021	0.0033	0.0050
I	0.0017	0.0032	0.0047
N	0.0023	0.0034	0.0048
D H	0.0023	0.0035	0.0050
I E	0.0020	0.0036	0.0052
V I	0.0022	0.0034	0.0056
I G	0.0018	0.0037	0.0055
D H	0.0019	0.0032	0.0054
U T	0.0020	0.0035	0.0048
A	0.0020	0.0036	
L	0.0016	0.0033	
	0.0022	0.0038	
Averaged	0.0020	0.00345	0.00508

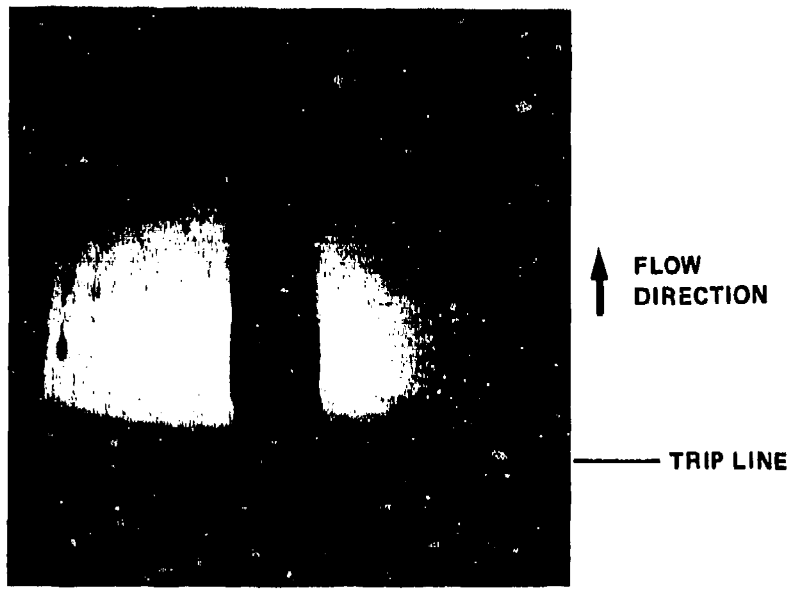
Table. 2 TEST CONDITIONS

M	$Re_c \times 10^6$	$\alpha_{t/c}$	Disk Height	Grit No*	Grit * Height
0.765	4.0	0.05	0.0020	220	0.0032
	6.0			" "	" "
	8.0			280	0.0015
	10.0			" "	" "
↓	15.0	↓	↓		
0.765	4.0	0.05	0.0035		
	6.0				
	8.0				
	10.0				
↓	15.0	↓	↓		
0.765	4.0	0.30	0.0035	180	0.0030
	6.0				
	8.0			↓	↓
↓	10.0	↓	↓		
0.765	4.0	0.30	0.0050		
	6.0				
	8.0				
↓	10.0	↓	↓		

* Data with grit tripping are taken from Reference 9.



UPPER SURFACE



LOWER SURFACE

FIG. 1: SURFACE FLOW VISUALIZATIONS AT THE UPPER AND THE LOWER SURFACE OF THE AIRFOIL MODEL, DISK TRIPPING, $M_\infty = 0.770$, $Re_C = 4.3 \times 10^6$, $\alpha = 2°$, $x_T/c = 0.05$, $k = 0.0020$ INCHES

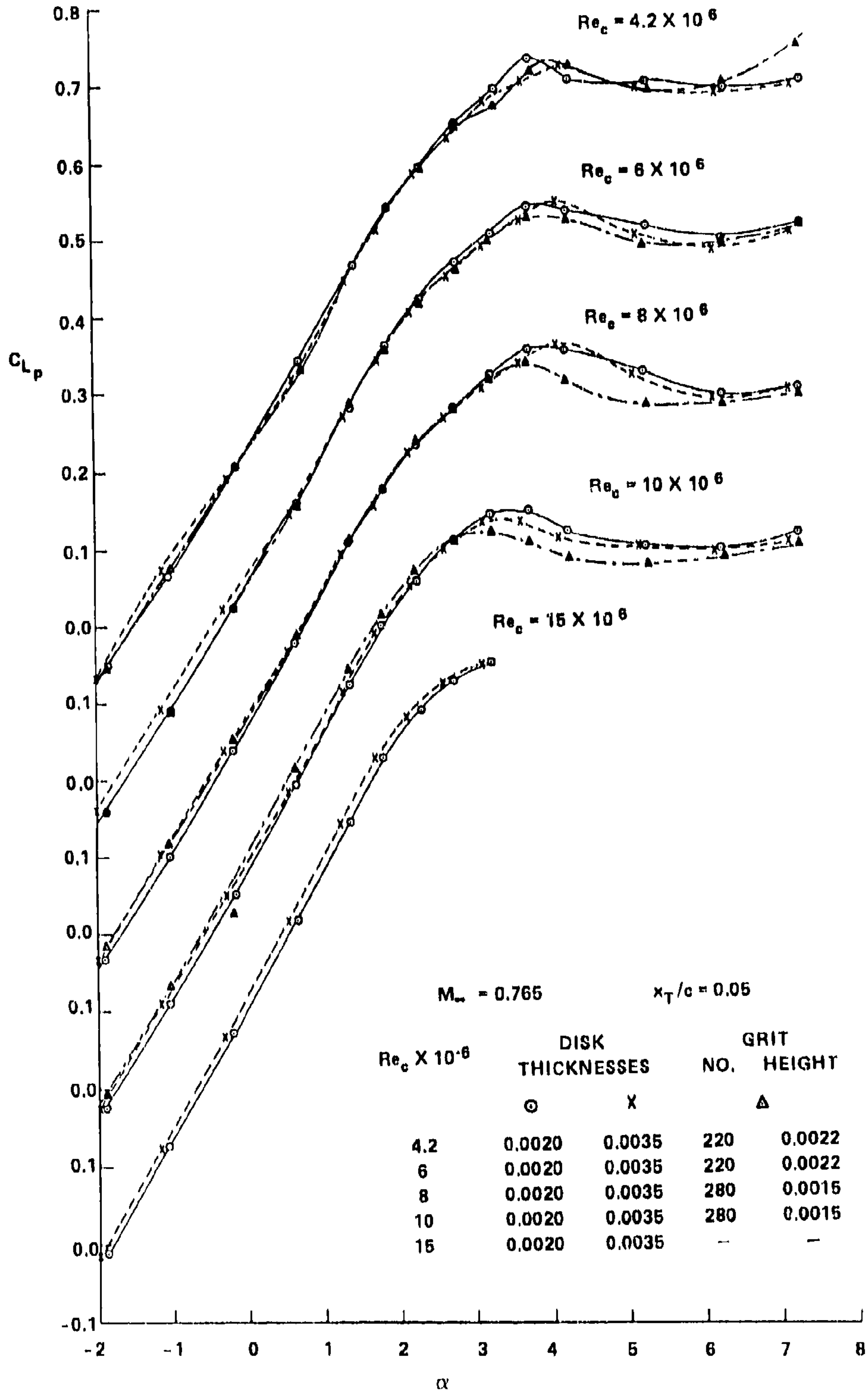


FIG. 2: LIFT VERSUS ANGLES OF ATTACK AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, $x_T/c = 0.05$

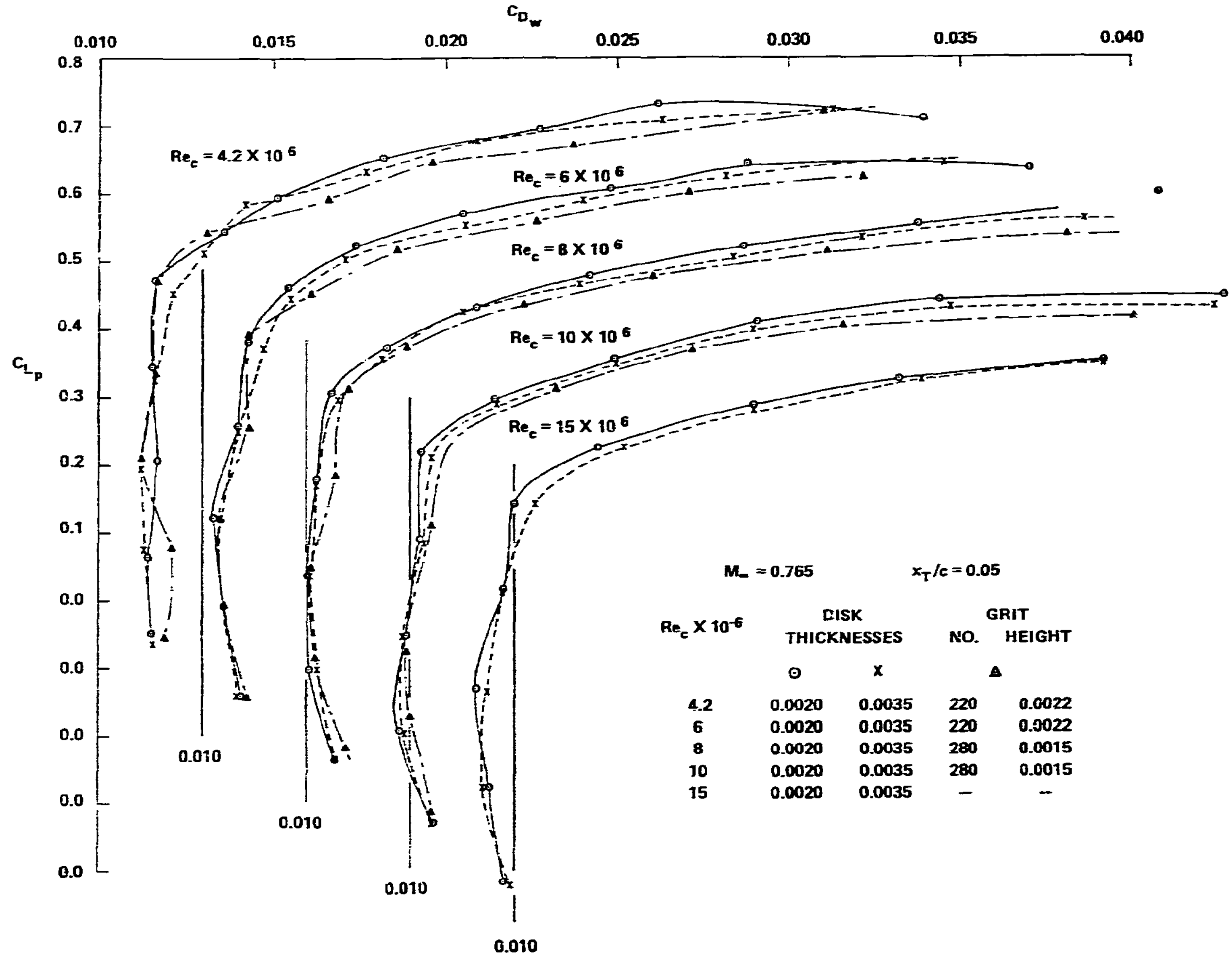


FIG. 3: DRAG VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, $x_T/c = 0.05$

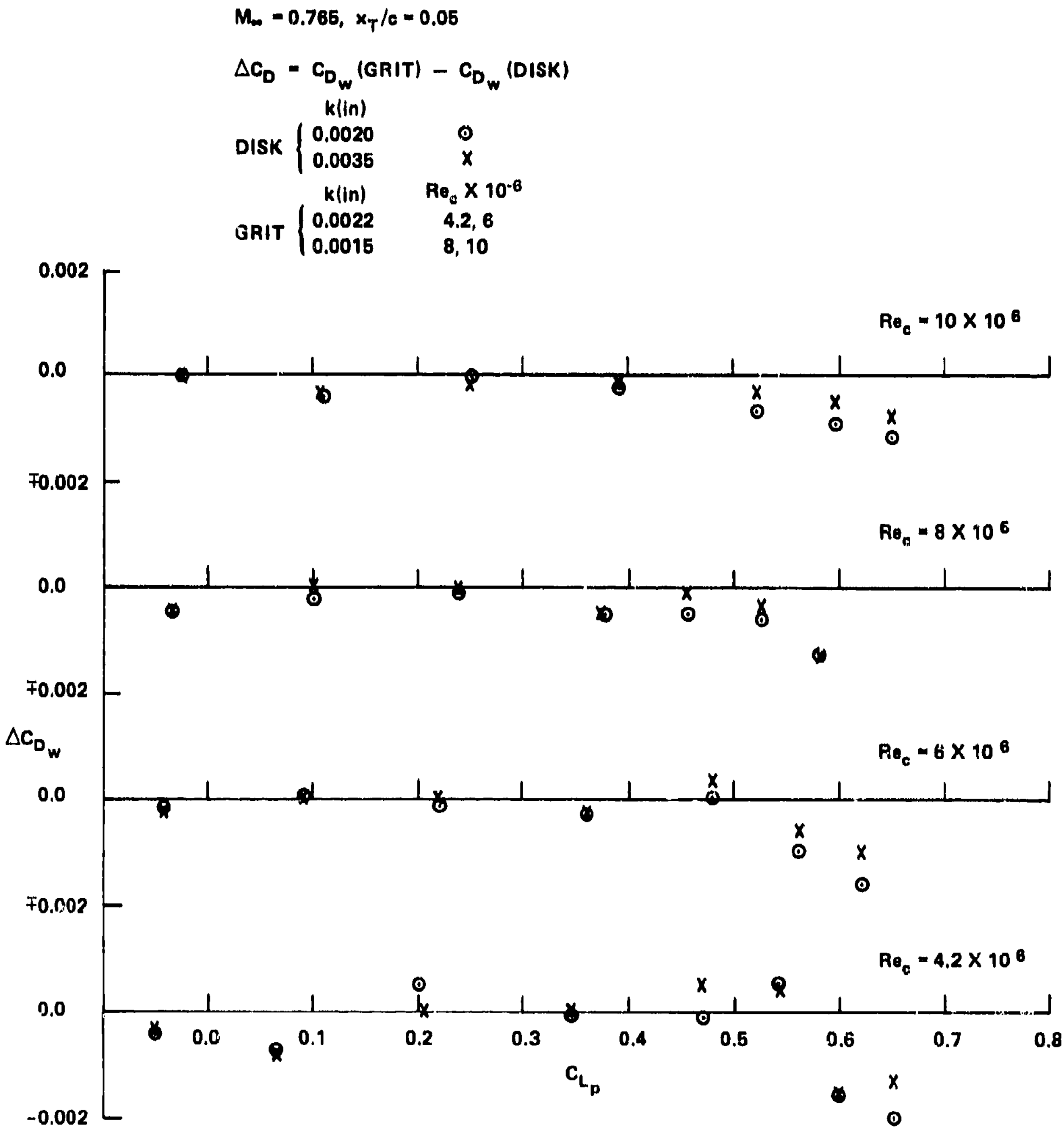


FIG. 4: DRAG DIFFERENTIAL BETWEEN GRIT AND DISK TRIPPINGS AT VARIOUS REYNOLDS NUMBERS, x_T/c = 0.05

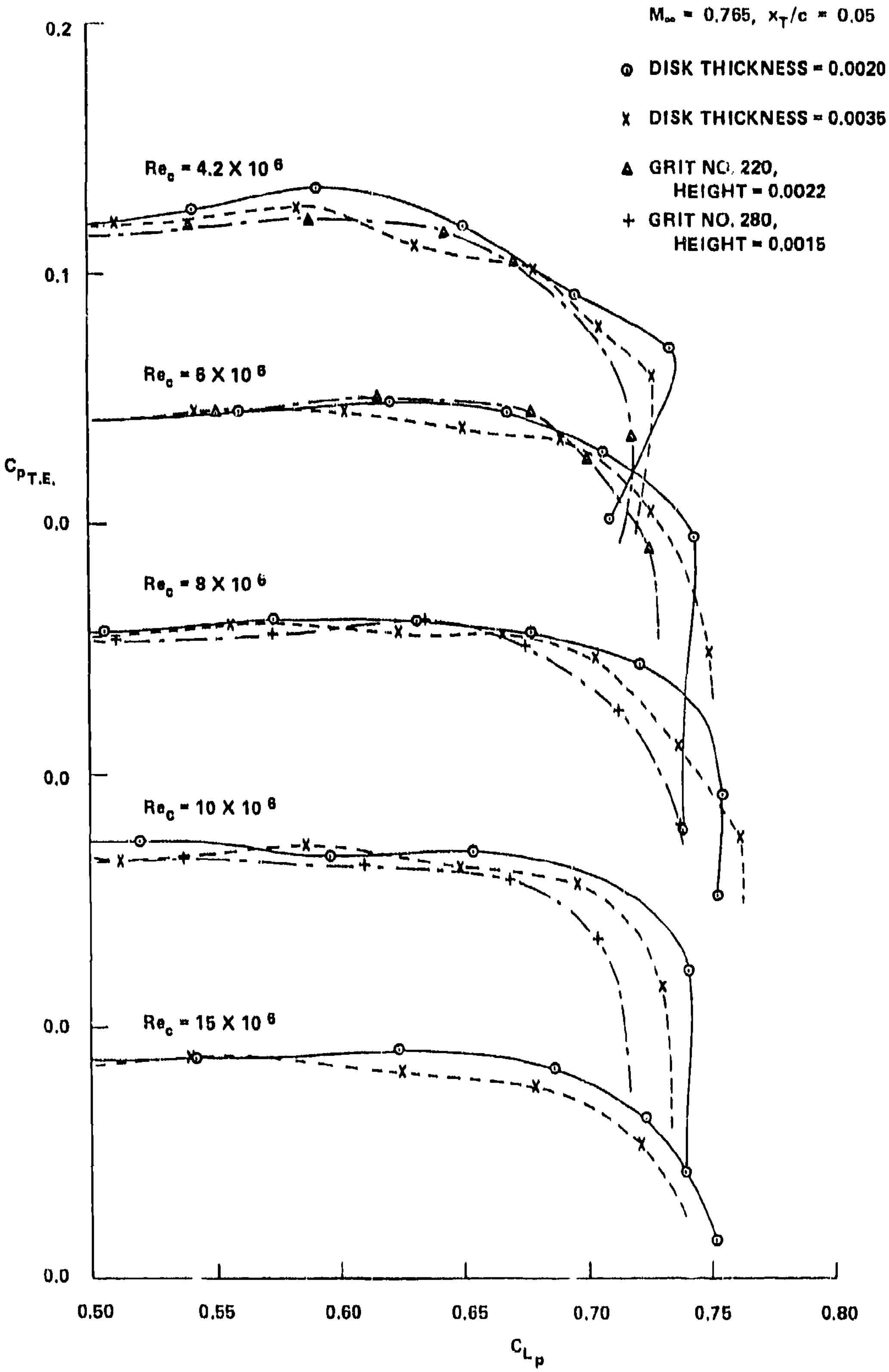


FIG. 5: TRAILING EDGE PRESSURE VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, x_T/c = 0.05

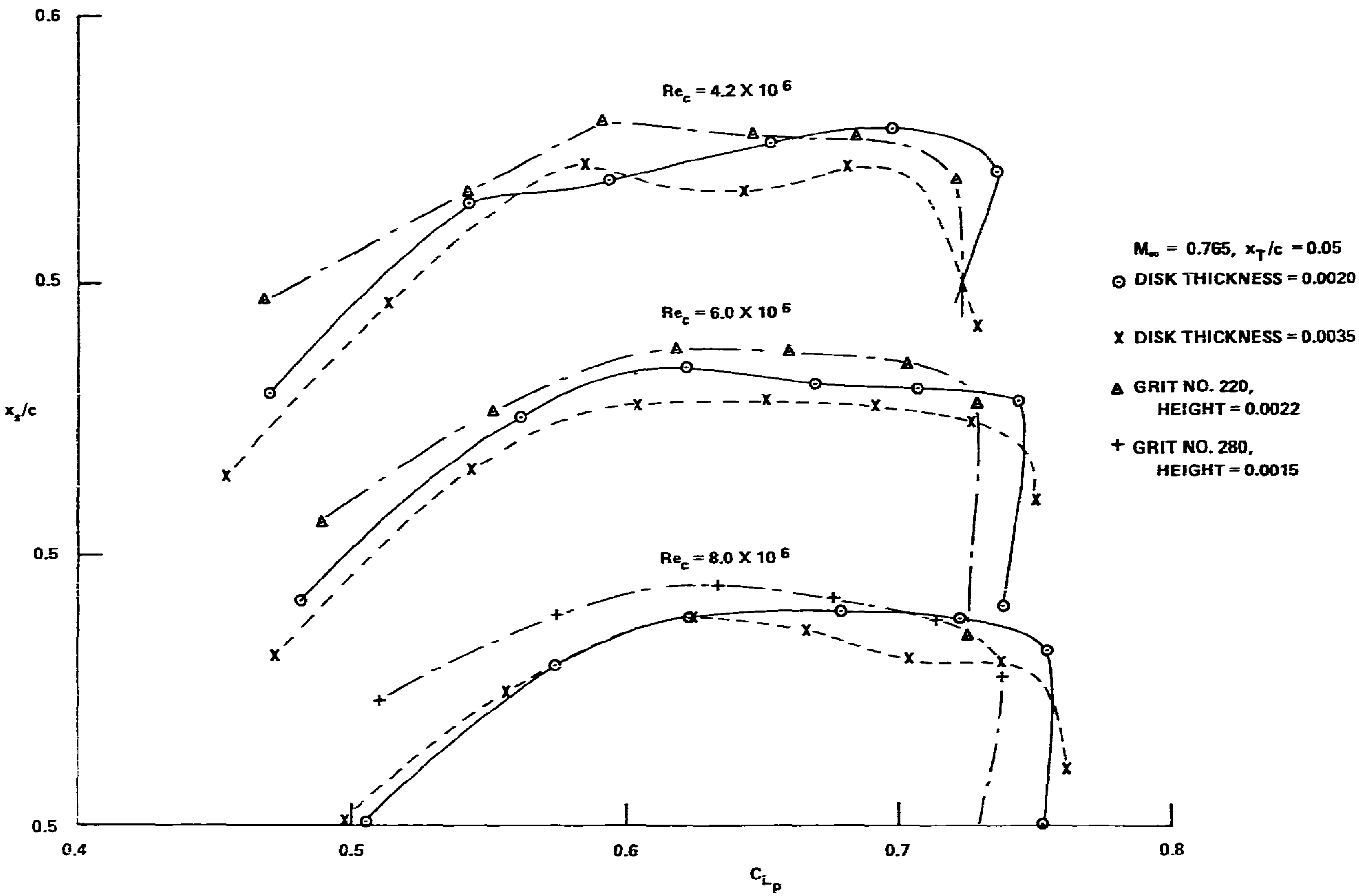


FIG. 6: SHOCK WAVE LOCATION AT THE UPPER SURFACE OF THE AIRFOIL VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, x_T/c = 0.05 (Cont'd)

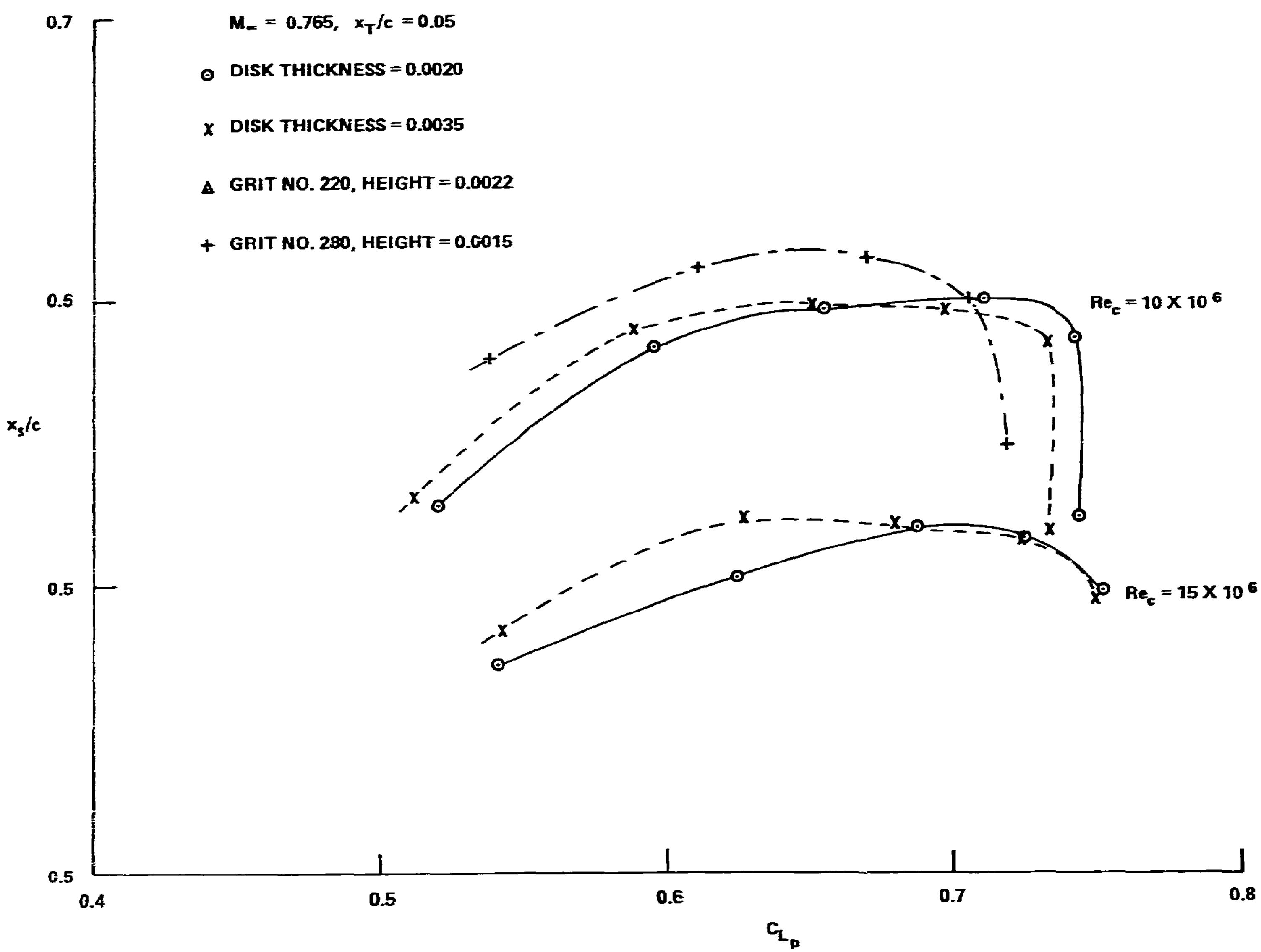


FIG. 6: SHOCK WAVE LOCATION AT THE UPPER SURFACE OF THE AIRFOIL VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, x_T/c = 0.05

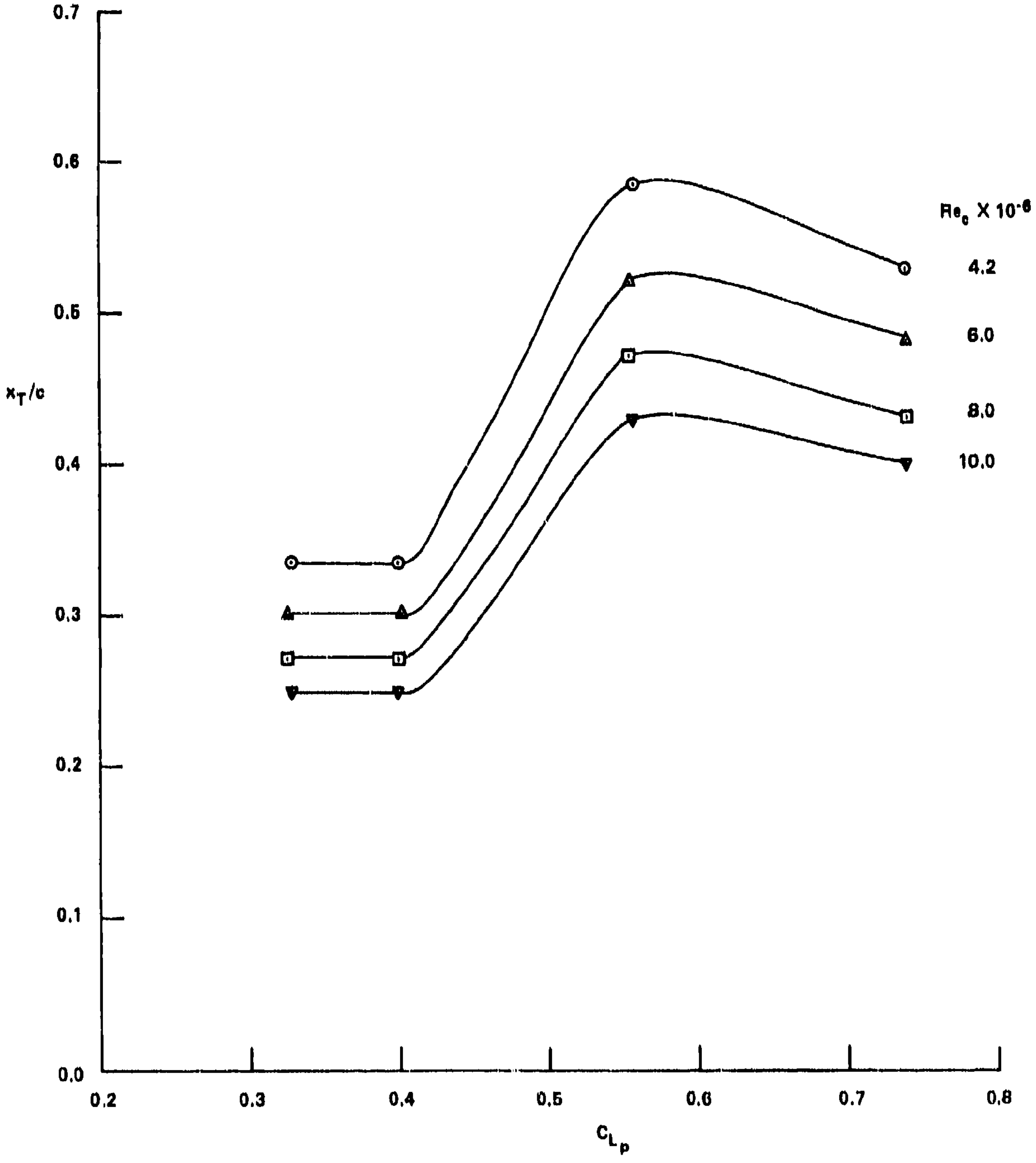


FIG. 7: ESTIMATIONS OF NATURAL TRANSITION LOCATIONS AT THE UPPER SURFACE OF THE AIRFOIL, M_∞ = 0.765

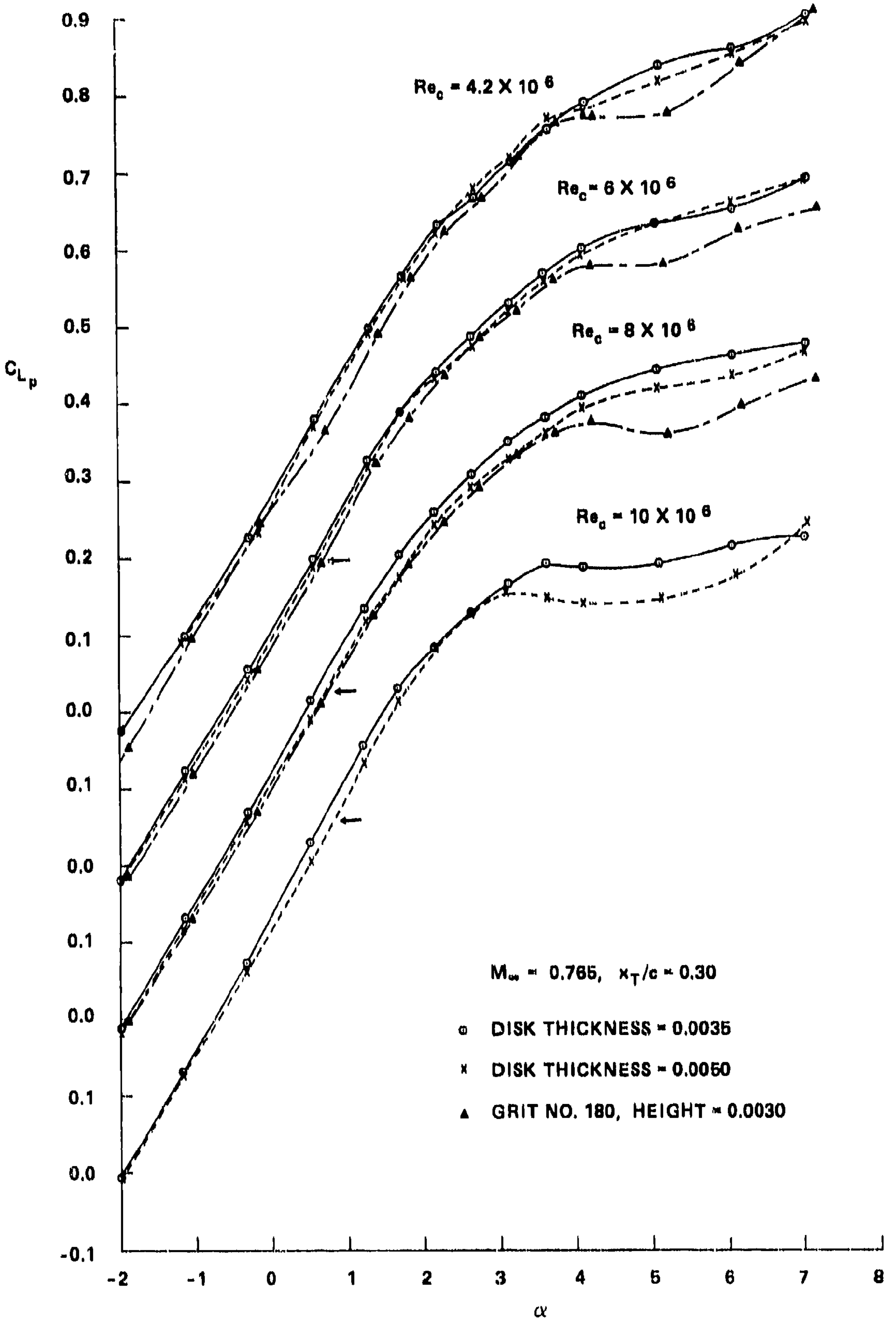


FIG. 8: LIFT VERSUS ANGLES OF ATTACK AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, x_T/c = 0.30

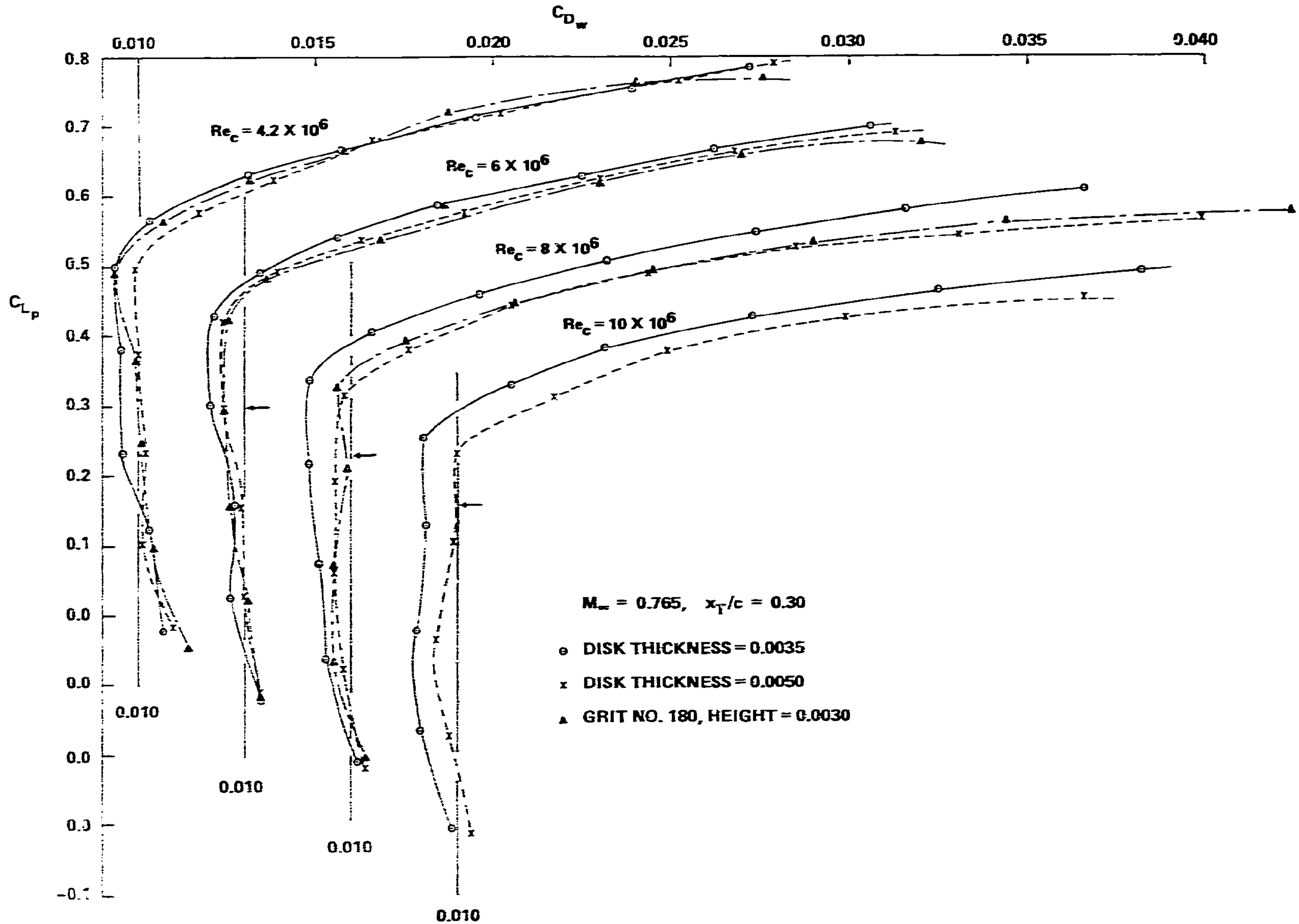


FIG. 9: DRAG VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, $x_T/c = 0.30$

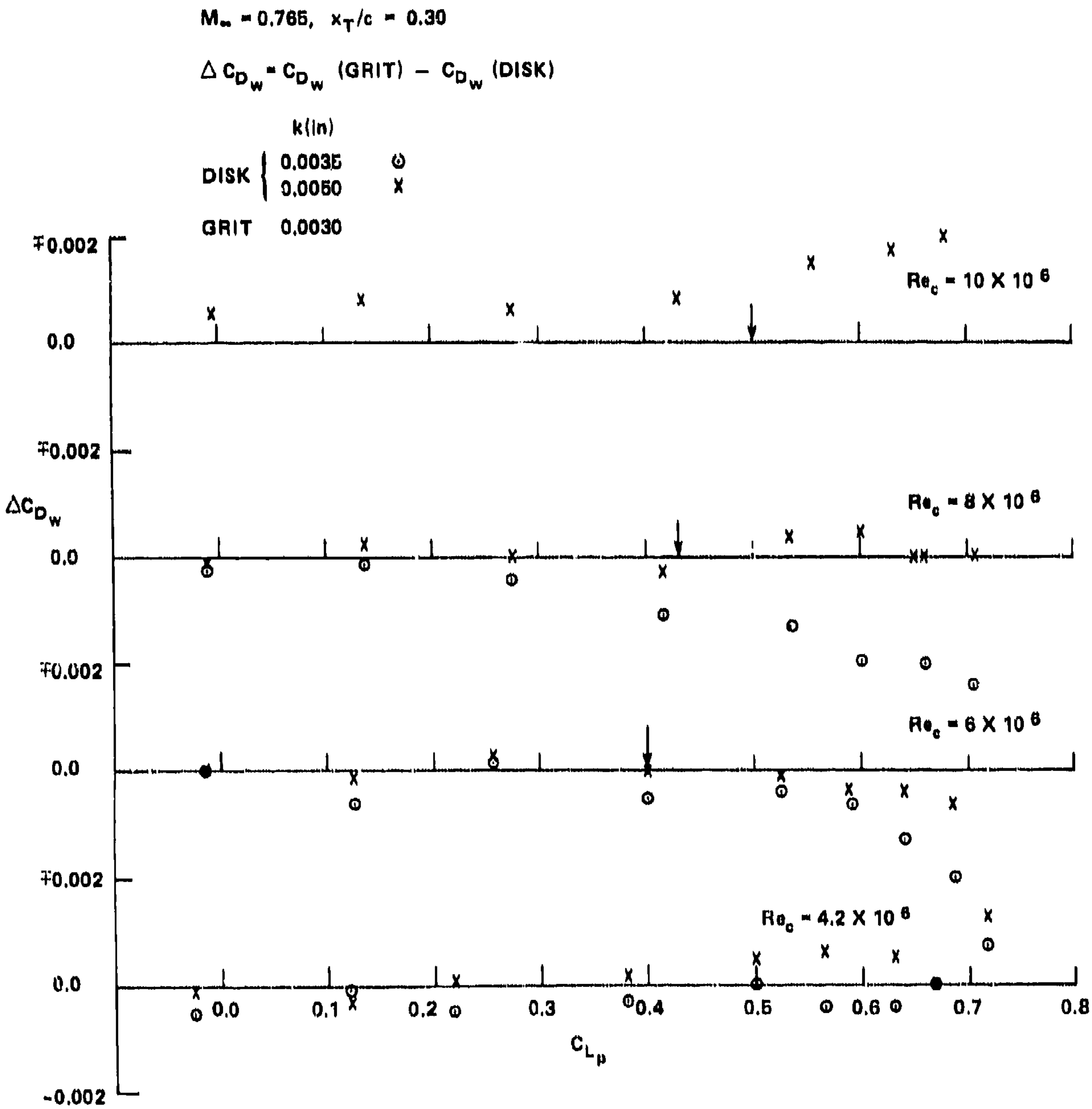


FIG. 10: DRAG DIFFERENTIAL BETWEEN GRIT AND DISK TRIPPINGS AT VARIOUS REYNOLDS NUMBERS, x_T/c = 0.30

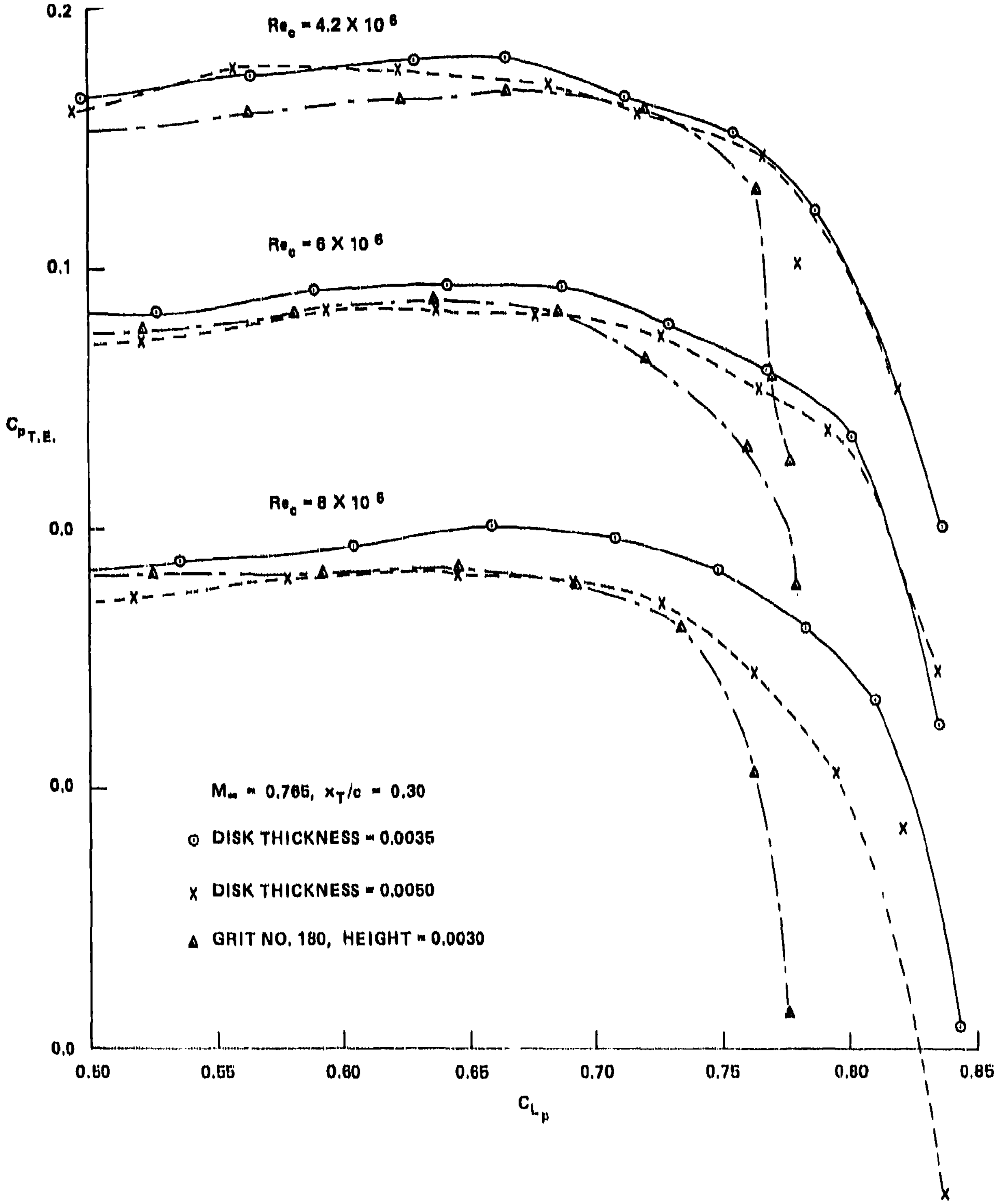


FIG. 11: TRAILING EDGE PRESSURE VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, x_T/c = 0.30

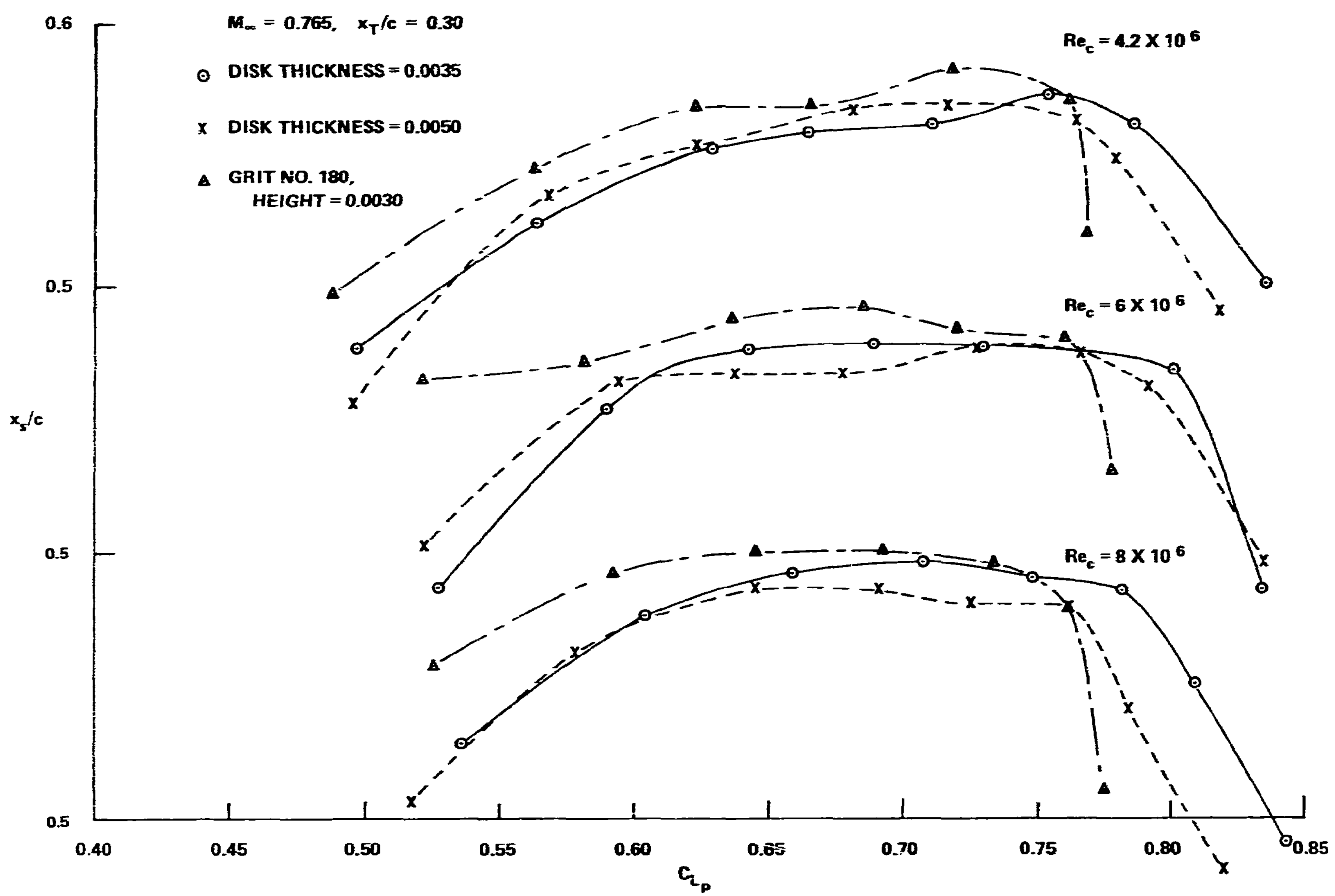


FIG. 12: SHOCK WAVE LOCATION AT THE UPPER SURFACE OF THE AIRFOIL VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH DISK OR GRIT TRIPPINGS, $x_T/c = 0.30$

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4 Comparison of Boundary Layer Trips of Disk and Grit Types on Airfoil Performance at Transonic Speeds

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DESCRIPTORS (KEY WORDS)/MOTS-CLÉS

1. Boundary layer transition
2. Supercritical wings
3. Laminar flow airfoils

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SUMMARY/SOMMAIRE

The effects on aerodynamic performance of a supercritical airfoil applying disk or grit tripping for boundary layer transition has been investigated for a typical supercritical airfoil at transonic speeds. It is observed that by allowing the laminar flow passing through the space between the disks, transition takes place a short distance downstream from the disk trip line. The boundary layer developed downstream from the disk trip is therefore slightly thinner than that from a grit trip. The vortex generating mechanism of the disks may also enhance this development. This small difference has negligible effect on aerodynamics of the airfoil at low lift. However, at high lift, the difference in boundary layer developments is amplified by the strong shock wave and the severe adverse pressure gradient. The thinner and more energetic boundary layer induced by the disk trip will yield higher lift, lower drag and higher trailing edge pressure.

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